August, 1919. Botanical Series. Vol. X, No. 3.

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STUDIES IN INDIAN SUGARCANES, NO. 5

ON TESTING THE SUITABILITY OF SUGARCANE VARIETIES FOR DIFFERENT LOCALITIES, BY A SYSTEM OF MEASUREMENTS. PERIODICITY IN THE GROWTH OF THE SUGARCANE

BY

C. A. BARBER, C.I.E., Sc.D. (Cantab.), F.L.S

Government Sugarcane Expert, Madras

MAR 4 1958

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

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BY

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FOREWORD.

The great advances made in agricultural science during recent years, by the application of well-arranged series of experimental plots, has thrown somewhat into the background the importance of careful observations on the ordinary crops grown, and the lessons which can be drawn from their variations. The laying down of a series of experimental plots and tabulating their results at crop time is a comparatively simple matter, and the equally important regular observation of the plots at intervals is more laborious and is not always attended to. A well-known experimentalist has, indeed, asserted to the writer, that such observations are altogether *ultra vires*, and that the plots should be only visited when sowing is taking place and the reaping done. While something may be said for this point of view in permanent plots, when the results are recorded over a long series of years, we cannot regard it as justified for general work on our Agricultural Stations, when it is desirable to obtain definite results within as short a time as possible. It has been found that the periodic notes taken of experimental plots during growth, as was regularly done at the Samalkota Sugarcane Station by the author, were often quite sufficient to explain apparent anomalies in the results, thus saving years of repetition, and it was usually found that these results could be forecasted with tolerable accuracy some months before harvest. The present paper, prepared in 1917 for the Lahore meeting of the Indian Science Congress, emphasizes this side of agricultural research. As will be seen in the context, it is not intended in any way to discount the value of the experimental method, but to explain the fact that there are cases when it is inapplicable and that, in such cases, series of careful observations, although more difficult and laborious, may be attended with useful results. To quote a remark in *Nature* (p. 203, May 16th, 1918), "Dr. Balls' comments on the short article on 'Cotton-growing Statistics' in the issue of this journal of April 11th, opens up a wide and interesting feature in scientific research, namely, the value of observed data and their interpretation." Owing to the lack of space, and the general character of the work on the Cane-breeding Station at Coimbatore, we have not been able to introduce much experimental work in the plots. *Observations* have, however, been regularly carried out for the past six years, and several Memoirs have already been issued, giving some of the interpreted results of such observations. The present paper gives yet another instance of such work, and it has been decided to publish it practically as it stands, although obviously incomplete in some respects, in that there seems to be little prospect of the longer Memoir projected being completed. It is considered that the details given sufficiently demonstrate the method proposed.

Coimbatore,
October, 1918.

STUDIES IN INDIAN SUGARCANES, No. 5.

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[Received for publication on 9th December, 1918.]

I. Summary of literature on growth in length of the sugarcane.

A writer in the *Louisiana Planter* of September, 1916, has drawn attention to the great growth in length of the sugarcane in the Southern States during the moist, forcing heat of July and August. He claims that, not infrequently, two to three joints are added per week and that these are well formed and from four to six inches in length, "and are apparently much finer canes than are generally grown in the tropics." A further statement in the November number of the same journal gives the data on which these figures are based and, incidentally, throws light on the vegetative period in this tract. Careful measurements made by a planting correspondent, extending over four years, show that the cane is about a foot long at the beginning of July, increases by 30 inches both in July and in August, 18 in September, 12 in October, and then practically ceases to grow. The author draws attention to the economic importance of this class of work, especially with regard to the decision as to which canes are best suited to different tracts of country. He emphasizes the absence of exact data and suggests that such work should be taken up by the experimental stations. The method employed by the planter was very simple, in that stakes were driven into the ground and the canes laid along these at successive periods and measured.

Studies in the growth in length of the different parts of the cane plant have occupied workers in Java at intervals for many years, although the

importance of the subject from the factory point of view has barely been realized. Kobus[1] (1887–1893) made a study of the growth in length of the lamina, and gave details as to the extent to which the inner structure was completed in leaves of different length. He pointed out that the lamina attained its full growth far sooner than the sheath. We have not had the opportunity of seeing Kobus's papers, and quote this from that of Kuijper mentioned below. Kamerling[2] issued an important paper in 1904, and quite recently Kuijper[3] has returned to the subject in 1915, and these papers deserve careful reading.

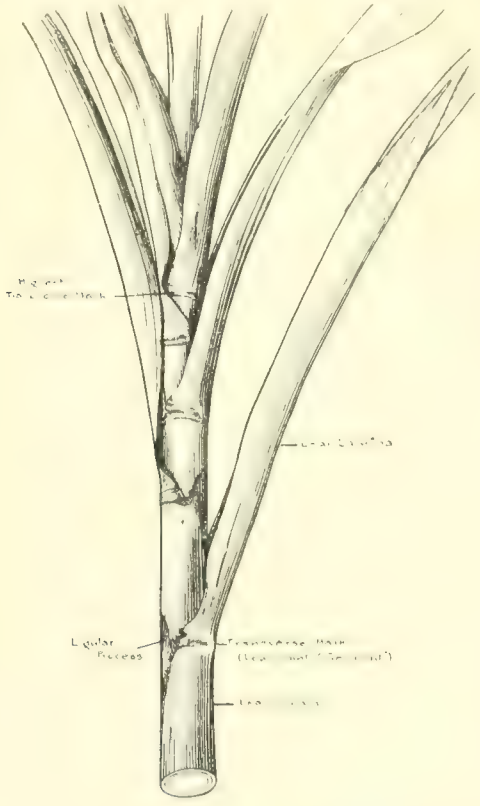
One of the greatest difficulties in measuring growing canes is due to the fact that the portion in actual elongation is permanently enswathed in a mass of leaves which cannot be removed without disturbing the growth. Observation of the ends of these leaves cannot be used in measurement because of the constant variation in length of successive leaves during the growing period. It becomes necessary to find some definite external point on the shoot which bears a constant relation to the growing point of the stem within. Kamerling set himself to find such a point. His object was to study the rate of growth in different fields and varieties, and to replace the general terms in use, such as "rapid," "slow," "moderately slow," and so on, by exact measurements, at the same time pointing out the importance of such work for the factory. By determining the rate of growth under certain well-defined conditions, he claimed that we should be in a position not only to decide the fitness of a variety for its locality but also to fix on general measures whereby unsatisfactory growth might be remedied. He first of all found that there is a sequence of growth in length in the lamina, leaf sheath and stem of a very definite character. The lamina first grows in length, rapidly unfolds itself and ceases from any further increase ; as soon as this is completed, the energy of growth is transferred to the sheath. It quickly elongates and pushes the lamina into the air and light and, in its turn, ceases from further growth in length. Lastly, when the leaf sheath has finished growing, the stem internodes, hitherto merely a series of flat, superposed discs, suddenly elongate by the expansion of their cells and cease to grow in length after a very short time. The sheaths thus complete their growth in length before the internodes commence to elongate, and their further apparent growth is due to the increase

[1] Kobus, J. D. Bijdrage tot de kennis van den bouw en de ontwikkeling van het suikerriet. I and II, Nos. 19 and 30 of the *Mededeelingen van het Proefstation Oost-Java*, 1887–1893.

[2] Kamerling, Z. De lengtegroei van het riet, *Archief voor de Java-Suikerindustrie*, deel XII, 1904, page 997.

[3] Kuijper, J. De groei van bladschijf, bladscheede en stengel van het suikerriet, *Mededeelingen van het Proefstation voor de Java-Suikerindustrie*, V, 8, 1915.

in length of the internodes to which they are attached. In the young shoot each leaf sheath is entirely covered by the one outside it, while it is yet undeveloped, but the moment when it emerges from this protection Kamerling shows to coincide with its cessation of growth. The tops of two successive sheaths are now close together, and any further separation is due to extension of the stem which at this period commences to elongate. The top of the leaf sheath is the place where it joins the lamina, and Kamerling selected this point which he calls the "blad-gewricht" (leaf joint), as the one by the observation of which he could indirectly observe the growth in length of



young joints of the stem apex (*see* Fig. above). This demonstration of Kamerling's has been found to be justified, *on the assumption that all of the mature leaf sheaths are of equal length.* He measured a series of leaf sheaths in different canes and soon found that, while the differences in their length in fully grown parts of the cane plant were very small, both at the beginning and end of the vegetative season the leaf sheaths were of different sizes. The first sheaths are very small, these successively increase in length until they reach a fairly

uniform maximum, and this is maintained during active growth. Towards the end of the season, however, the sheaths again diminish in length. He made a distinction between the actual growth of the young internodes, and their "apparent" growth as judged by the observation of the leaf joint, and showed that, while the difference between the actual and apparent growth is small during the period of full growth of the cane plant, it is large at the beginning and the end of the season. Kamerling then tried a method of measuring the growth of the stem directly, by removing the leafy mass around the actively elongating portion, marking it and covering it with tin foil, and measuring it again after 24 hours. The results agreed with those already obtained, showed that the region of elongation was confined to few joints, and that, in these, the top of each joint ceased growing first and the lower part continued elongating after the upper had ceased to alter, that is, that the region of most active growth in length in each joint was basi-petal. But such harsh treatment of the young growing parts soon introduced irregularities in development, and Kamerling's main results depended on the indirect method mentioned above.

To Kuijper belongs the credit of overcoming once and for all these difficulties. After trying various methods, he hit upon the ingenious plan of piercing the whole growing shoot with a darning needle (finer instruments encountered too much resistance), starting with a full-grown leaf sheath on the outside, which showed no further movement, and working upwards. A series of holes were thus made through the whole mass of growing parts, and, as growth took place, these holes were pushed up in various degrees in the different organs inside. After a period of six days the relative position of the holes was studied, and their change in position gave an accurate measure of the growth which had taken place in each organ. By a multiplication of the initial holes at distances of about one centimetre up the outer leaf sheath, he was able to state definitely in what part of each organ growth was most rapid, as all that remained to be done was to dissect out the mass after a stated interval, lay out the parts, and measure the vertical distances between the holes. While this method was found to disturb the growth in very young parts, it fully justified its use, and the general results obtained by Kamerling were substantiated, but, by a series of *actual*, in place of *inferred*, measurements. The basi-petal tendency of the zone of most active growth in each internode was confirmed, and it was found that the leaf sheath and lamina behaved in a similar manner. Kuijper's work was, in the main, instituted for a study of certain diseases of the shoot, which appeared to depend on the relative growth of the young parts, and the previous work of Kamerling

Length of Leaf-sheath Curves in Khari, Sabour, 1916-17

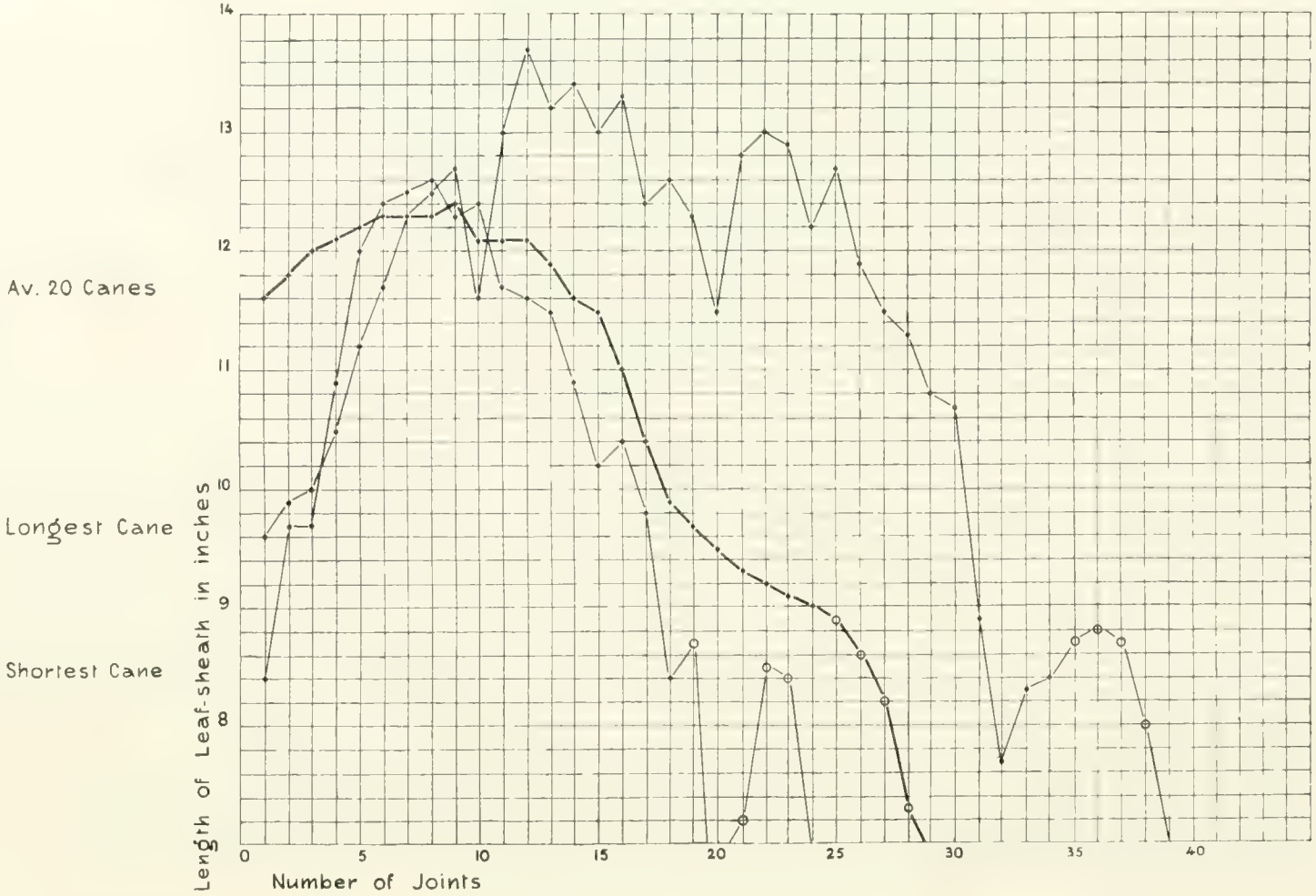


PLATE I.

did not give the accurate figures required for this. He fully endorsed the selection of the uppermost visible leaf joint for measurement in stem growth, safeguarding it, as was done by Kamerling, at the beginning and end of the season. We are indebted to him for the first clear demonstration of what goes on inside the growing portion of the cane shoot.

An interesting piece of work on the growth of the cane was done by Taluqdar at Sabour Government Farm in 1914.[1] Here iron stakes were driven into the ground to a great depth, at the commencement of the season, and marks made to indicate the original ground-level. Measurements were taken from this point to the leaf joint, at intervals of a fortnight, in a series of cane bushes belonging to three different varieties, *Khari*, *Shakarchynia*, and *Buxaria*. Taluqdar followed the Java practice in selecting the leaf joint, but used a coloured mark which occurs across the base of the lamina at this point. This he calls the "ligular band," and in previous Memoirs we have termed it the "transverse mark" on the leaf sheath; it is usually quite easy to see and is often brightly coloured, forming one of the most striking features in the growing shoot (Fig. on p. 157). There appear to us to be two points in which the accuracy of Taluqdar's measurements may be criticized. In the first place his observations commence very early in the life of the plant and continue to the end of the growing period, and he does not appear to have noted that the lengths of the leaf sheaths diminish at these periods. He assumes a steady uniformity in length of leaf sheath throughout the growing period. Secondly, the work of the Java men was done on thick tropical canes, such as *Cheribon*, *Lœthers*, *P. O. J. 100*, and these differ a good deal in many respects from the indigenous Indian canes used by Taluqdar. It is by no means certain that the ends of the leaf sheaths are a safe point on which to base the measurements of stem growth in Indian canes. In fact, the leaf sheaths appear to differ in length very much more in the latter class of canes. Some measurements, made by the author, of successive leaf sheaths in *Khari* growing at Sabour, are appended. The average curve of the length of leaf sheath in the whole twenty canes measured has been plotted out and the curves of the longest and shortest canes have been added, *i.e.*, those with the greatest and smallest number of joints (Plate I). It will be seen that the leaf sheaths vary very greatly in the general curve during the course of growth, whereas, in the individuals, there are often differences in successive joints of over an inch. An analysis of these curves may make our meaning clearer. Leaving out the first five, until the leaf sheath has attained to its full length, and the last eight, when the leaf

[1] Taluqdar, J. M. Notes on the growth of Sugarcane. *Bihar and Orissa Agricultural Journal*, Vol. III, No. 1, April, 1915.

sheaths rapidly diminish in length owing to the immaturity of the joints, we have the following differences in the length of leaf sheaths. The average difference in length of adjoining leaf sheaths, in the shortest cane, is 0·44″, and the five greatest differences are 1·4″, 0·7″, 0·7″, 0·7″, and 0·6″. In the longest cane, the average difference is 0·59″, and the five greatest are 1·8″, 1·4″, 1·3″, 1·3″, and 1·1″. Compare with these figures those obtained from the three examples, given by Kamerling, of thick canes grown in Java :—

(1) Average difference 0·11″, the five greatest being 0·3 , 0·2″, 0·2″, 0·1″, 0·1″.
(2) ,, 0·23″, ,, 0·6″, 0·4″, 0·4″, 0·4″, 0·2″.
(3) ,, 0·02″, ,, 0·1″, 0·0″, 0·0″, 0·0″, 0·0″.

It appears from this that it might be well for Kuijper's work to be done again in a series of indigenous Indian canes, and, until this is done, it is unsafe to use the Java method for the accurate measurement of growth in length of young internodes by merely observing the distances of successive transverse marks.

Taluqdar's measurements extended from May to early November, but as the period of tillering was not completed until the beginning of June, the earlier measurements only refer to a small number of shoots, while at the end of the season very many had been destroyed by moth-borers. Five or six months may be taken as the period of active growth, and this received an enormous impetus in July when the rains set in, thus presenting great similarity with the course of events already referred to in Louisiana. An attempt is made to determine the influence of temperature and moisture on growth, and the general conclusion arrived at is that these two factors act in common and that, as soon as one of them declines, the effect of the other is neutralized. In the tables it is seen that the period of growth is limited at both ends by declining warmth and moisture. Growth in the tropics is very different from that in Louisiana and North India, in that the temperature there never sinks so low as to be ineffective and, when moisture fails, irrigation is resorted to. The usual period of growth is twelve months and, consequently, larger crops are obtained.

II. The method of cane measurements adopted and the material used.

The method adopted in this paper is altogether different from those referred to above. It is, namely, to take the cane at crop time and measure the parts, and from these measurements to try and infer the general growth conditions at the place where the crop was grown. The length and thickness of the different organs vary much in different places, and, from their study, it is attempted to form an opinion as to the relative suitability of such places

EXPLANATION OF PLATE II

Photographs of palmyra topes in the Madras Presidency

The upper picture shows normal, uninjured growth. This plantation is about half a mile from the Cane-breeding Station at Coimbatore. It is called the "Thomas" tope after a Collector of Coimbatore, much given to tree-planting, and was planted in his time. The period of his collectorate was between March 1848 and May 1862, and the tope is therefore 60 to 70 years old.

The lower picture shows the effect of a great storm of wind in a palmyra tope in the Godavari District. The storm occurred some 28 years before the photograph was taken (*see* Note on p. 161), and its effect is seen in the simultaneous bending of many of the stems in one direction.

EXPLANATION OF PLATE II

Photographs of pollarded tops in the Madras Presidency

The upper picture shows normal unburned growth. The plantation is about half a mile from the Mapperaying Station at Coimbatore. It is called the "Thomas" Tope after a Collector of Coimbatore, under whom the trees were planted and was planted in his time. The period of his collectorate was between March 1848 and May 1852, and the tope is therefore 60 to 70 years old.

The lower picture shows the effect of a great storm of wind in a palmyra tope in the Godavari District. The storm occurred some 25 years before the photograph was taken (see Note on p. 161), and its effect is seen in the simultaneous bending of many of the trees in one direction.

to the varieties grown. This method was not adopted because there was any special fault to be found with those described above, but simply because it was the only possible one in the circumstances and for the purpose in view. In place of periodic observations made on a few selected plants during their growth at one place, a large series of plants grown at widely different stations are compared. Early in the life of the Cane-breeding Station it was noted that, as one passed from the frost-visited region of the Punjab, in a south-easterly direction along the Himalayas and in a southerly direction down the Peninsula, one constantly met with larger varieties of canes, even when these belonged to the same natural groups. It was easy to suggest that this was, in the main, due to the forcing effect of the warmer, moister climate. And seven North Indian canes of those collected at Coimbatore were distributed to Taliparamba, on the Malabar coast, and Samalkota on the Coromandel, in order to note the effect on these varieties of the soil and climate. A scheme of accurate measurements was instituted towards crop time, and these soon showed that there were marked differences in the growth of the plants in these two localities and at Coimbatore itself. Later on, these measurements were introduced for the study of the varieties in different parts of the country, including places in North India, and there are now ten localities from which we have a series of such measurements recorded. With this mass of material available, it was thought worth while to see if some expression could be evolved by which the influence of each locality on the growth of the cane could be distinguished.

That, from the study of the various parts of such a completed plant, some insight may be obtained into its vicissitudes during growth, is not altogether unreasonable. Any one accustomed to the study of growth rings in dicotyledons is aware that they differ according to variations in the year's season and those of successive years. At certain places in the Madras Presidency, all the palmyra palms may be seen suddenly to narrow at about the same distance from the ground, or to show a marked bend in the same direction, indicating surely that, at that period of growth, the young plantation encountered some storm or period of stress[1] (Plate II). In the cane itself it has

[1] Since writing the above, Mr. W. McRae, the Madras Government Mycologist, has very kindly placed at my disposal a photograph taken by him of a palmyra tope, showing the effect of a storm; and he has given me the following note concerning it: "The photograph of the palmyra palms with bent trunks was taken in October 1911 in the village of Mallavaram, in Cocanada taluk of the Godavari District. The tope was situated near the sea-shore. The palms were said by the village Munsiff to have been bent over in a storm that occurred 28 years ago, and he was able to fix the date because it happened in the same year as an important domestic occurrence."

been noted, in parts of Bengal, that it is easy to put one's finger on the part of the stem where the growing cane experienced the onset of the monsoon rains, whether because of differences of thickness and length of joints or the occurrence of abundant aerial roots. So too, the attack of a single moth-borer leaves its mark in a sudden diminution in thickness and length of the joints, those succeeding gradually recovering their normal size. The leaf scars of many dicotyledons engrave the history of the year's growth on the stem whether it be the slow growth of spring, when the scale leaves gradually change into foliage leaves, the putting forth of the branches, the rapid growth in the summer or the slowing down in autumn. So too, although less evident, there will be marks left in the joints of monocotyledons. My Assistant, Mr. T. S. Venkataraman, has shown that, in some coconuts growing on the Cane-breeding Station, there is periodicity in the vertical width of the bases of successive leaves, possibly connected with the seasons of the year, a fact which receives additional interest from the periodicity recorded below in the sugarcane itself. The mere study of the length of successive joints in a cane may therefore sometimes be of use in indicating differing growth conditions and some striking instances of this will be mentioned during the course of the paper. But many other measurements have been made as well, from which similar deductions could be made.

The system of measurements employed is fully described, and numerous examples are pointed, in Memoir No. 3,[1] but a summary is here given for the sake of clearness. As is natural, the chief importance is attached to the growth in length of parts. Twenty canes are chosen to represent any plot, safeguards being introduced to insure that they are average healthy ones at a distance from one another. These are first measured joint by joint as to length of lamina, leaf sheath and joint, and the results are so arranged that it is easy at any time to pick out the successive organs belonging to any one cane of the twenty. By a system of averaging (the difficulties of which need not detain us here), an ideal cane is built up for these twenty, and this is taken to represent the particular variety grown at that time and place. The measurements thus obtained are plotted out on squared paper and placed on record, as the appropriate curves of length of successive joints, leaf sheaths and laminas. Reference may be made to the curves already shown of *Khari* leaf sheaths

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 3. The classification of Indian canes with special reference to the Saretha and Sunnabile groups. *Mem. Dep. Agric. Ind., Bot. Ser.*, Vol. IX, No. 4, May, 1918.

grown at Sabour in 1917 (Plate I). Besides these measurements in length of organs, the numbers of joints are counted and the total length of formed cane is measured, and from these two figures is obtained the rate of cane formation per mensem while in the ground. The numbers of dead leaves are counted and the length of the cane covered by these (these two figures being taken as indicating the rate of ripening of the cane), the length of the shoot (unripened part of the plant) is recorded and the total length of the whole plant when laid out on the ground, the maximum width of the leaf and the average thickness of the stem. The latter measurement deserves special mention, in that canes vary in thickness in different parts and are generally oval in section. Each cane, when stripped, is measured at the middle, at the base, and at the highest matured joint. And these measurements have to be done in two planes, at right angles to one another, because of the ovalness of the cane, one being made in the plane of leaf attachment and one at right angles to it. The latter is almost invariably narrower than the former. These six measurements are averaged for each of the twenty canes, and the resultant of these is taken as the average thickness of the canes in the plot. Incidentally, ovalness of the cane is recorded, as the cane varieties differ in this respect, as well as the tendency to thicken upwards or downwards which characterizes different kinds of canes. All of these measurements are made on the same twenty canes, and the latter are so arranged in tables that all the measurements of each individual cane and joint may at once be seen, and any future work on correlation between the variations in size in different organs may be studied.

This material forms the basis of our work, and a comparison of these measurements determines the general lines on which our conclusions are framed. It becomes possible to compare the growth of the same cane in different places, the development of individual cane characters in different surroundings, and the manner in which different sets of conditions impress themselves on cane growth in general—whether favourably or the reverse.

The series of measurements obtained for each set of twenty canes, taken at one time and place, form together a "unit" observation. There are now some hundreds of these units collected, and many of them were utilized in the Memoir referred to above, for the purpose of distinguishing the growth characters of the Saretha and Sunnabile groups. But, in the present paper, only those dealing with the seven cane varieties distributed to Taliparamba

and Samalkota have been included. Eighty-nine unit observations on these varieties form the basis of the present paper.

The varieties dealt with are the following :—*Saretha*, *Chin*, *Khari*, *Chynia*, *Pansahi*, *Baroukha* (of Sabour and not of the United Provinces, a member of the Nargori group of canes), and *Mungo*. All of these have been examined at the Cane-breeding Station, at Taliparamba and Samalkota, and such of them as were found growing at the Coimbatore Central Farm, Nagpur, Sabour, Pusa, Partabgarh, Shahjahanpur, and Aligarh. The observations at the latter place are less complete, in that only six canes were measured and these at an early stage of growth, but they are included because they indicate certain well-marked characters which have still to be checked. A study of the agricultural conditions and the curves of growths obtained have led us to divide these places into three regions: (1) The Coimbatore Central Farm, Taliparamba, Samalkota and Nagpur represent *wet land*, continuously irrigated from tanks; (2) The Cane-breeding Station, consisting of slightly saline *garden land*, dry land irrigated from wells; (3) Gangetic alluvium. The latter region has of necessity been less fully studied than the rest, and in many cases the record is very incomplete. There are great variations in the curves obtained from these northern places, but it has not been found possible, with the data available, to subdivide the tract. Suffice it to say that there appear to be as great differences in growth in North India as in South India, and that the rate of growth appears to be greater in Aligarh, Shahjahanpur, and perhaps Sabour, than at Pusa and Partabgarh. The last named gives, in almost all cases, a less vigorous growth than in any other place of those observed. The Cane-breeding Station, with its handicap of well-irrigation and intractable soil with slight salinity, shows curves much more similar to those obtained in North India than any of the wet land places, thus justifying its selection for the work of raising seedlings for North India. It has been already stated that our record is to a certain extent incomplete. This was of necessity the case, in that the work of accurate measurements has gradually extended, and the object of the present paper was not at first held in view. But it is held that this will not invalidate the method, which can be much more easily employed when the opportunity occurs of putting down the same varieties in each place. This incompleteness has, in the present instance, entailed a great deal of labour, in that there are a number of points which need safeguarding, lest conclusions are arrived at on insufficient data. A statement is appended of the observations on which this paper is based, showing the number of units obtained for each variety at each place, and some of the pitfalls are detailed below with the means adopted of avoiding them.

TABLE I.

Unit observations of varieties and places.

	Garden land	Wet land				Gangetic alluvium					Total
	C.B.S.	C. F.	Sam.	Tal.	Nag.	Sab.	Pusa	Part.	Shah.	Alig.	
Months in ground	11	10	11	8½	11½	8	7½	9	9	6	..
Saretha .	4	2	2	3	1	..	2	1	..	1	16
Chin .	3	2	2	3	1	..	..	1	3	1	16
Khari .	2	1	2	3	1	2	..	1	1	1	14
Pansahi .	1	2	2	3	..	2	..	1	..	..	11
Chynia . .	1	1	2	3	..	2	2	..	..	..	11
Baroukha .	2	1	2	3	..	2	..	..	..	..	10
Mungo . .	2	..	2	2	..	1	2	..	1	1	11
Total .	15	9	14	20	3	9	6	4	5	4	89
Garden land	15	Wet land			46	Gangetic alluvium				28	89

In comparing the general growth of the cane plant in different places, it is, in the first place, necessary to consider the varieties observed there. *Saretha* and *Baroukha*, for instance, are characterized by comparatively enormous length of stems, while *Mungo* is a dwarf variety with very short joints and canes. As the latter cane is present in some places and not in others, we cannot obtain reliable figures of general cane growth for any one place by averaging the observations irrespective of whether *Mungo* is present or not. It would, again, be difficult to compare the cane growth as indicated by the units observed at Nagpur and Sabour, for there is only one of our seven canes grown in common at these two places. The following method has been adopted to overcome this difficulty. Stations are only compared by averaging the same canes grown on them. The Cane-breeding Station, Taliparamba, and Samalkota were first compared, as all of them had the whole series growing. Then the Coimbatore Central Farm was compared with these three, omitting *Mungo* altogether, which was absent on it. Nagpur was compared with these four, as well as with Partabgarh and Aligarh, only in respect to the measurements of *Saretha*, *Chin*, and *Khari*. Sabour was compared with the three localities which had its five canes, Pusa with the same three, Partabgarh with the first four, Shahjahanpur with four, and Aligarh with three. This method of course greatly increased the work, but it was considered the only safe way in which to compare the general growth of canes in different places.

Another factor here obtruded itself. In comparing Pusa with the three places in South India which had the same varieties growing, it was noted that *Mungo* does rather well in some respects at Pusa, while it does very badly

in South India. As it is probable that most of the cane varieties now under consideration would do worse in Pusa than in South India, its comparatively good *Mungo* gives it a more favourable position than it deserves. And, in the general summation, such cases have to be considered.

Again, in comparing the growth of different varieties, we have to consider the general character of growth at the place where they are observed. Certain varieties are better suited to certain places, and it is part of the object of this study to determine what kinds grow best in each locality. Taliparamba, for instance, is characterized by the formation of many, longish joints, and long canes of moderate thickness; Nagpur has few joints of great length, but these are thin and the leaves are narrow; Partabgarh develops all parts poorly, excepting the thickness of the stem and width of leaf, and so on. It thus becomes important to take into consideration the range of places from which unit observations have been taken, in comparing the relative growth of the organs of different varieties.

Due allowance must be made for the character of the season and the piece of land used during any year. This is not usually possible or necessary, but some extreme cases have occurred, showing that the influence of these factors cannot always be neglected. The most striking instance of this is in the two sets of observations made at Samalkota in successive years. The curves of length of joints in these two years differ so much that they might well have been obtained from two different places, and they bear the impress of the season during which they grow so strongly that a separate section is devoted, later on, to their study. The difference in the plots of land in two years at the Cane-breeding Station is also clearly reflected in the series of measurements obtained, as has been fully detailed in the Memoir mentioned above. These differences in successive years make it all the more necessary that the observations should be extended over several years at each place. It will be seen, from a reference to the table of observation units, that there are a number of cases where only one observation has been made, and in such cases the results should be regarded as more or less tentative and to require checking by further observations.

The time during which the observed crop has been in the ground has, naturally, a very considerable influence on the relative growth which takes place, and this is emphasized by the fact that early growth is more energetic than that taking place later on. The period of growth has been carefully allowed for, in that various measurements in length have been divided by the number of months which have elapsed between the dates of planting and examination. Generally speaking, the plots have been examined earlier in

North India than in South, but the habit of trashing the cane at Taliparamba has made it necessary to make the observations earlier there too. Now a study of the relative length of joints at different periods of growth shows that, within a short time of the commencement of joint formation, these become very long, soon reaching a maximum, after which they gradually diminish till near harvest time. The joints in the earlier portion of the year are therefore longer than in the later, and the values in the tables for North India and Taliparamba occupy a more favourable place than they should do, when compared with other localities. This is especially the case with Aligarh where only six canes were measured, only six months old. The apparently high position of Aligarh is thus somewhat discounted, and similar allowance must be made in certain other cases. But, on the whole, when it is possible to check it by comparing canes growing during equal periods, it has been found that there is less discrepancy caused by this factor than would be expected.

It is a different matter when we consider the average length of season in different parts of the country. As is well known, the period of cane formation in North India is very much less than it is in the warmer, tropical parts. Whereas the season of active growth is very short in North India, often hardly reaching six months, it usually extends to nearly twelve in the South. The figures representing growth per mensem give a great advantage to North Indian stations, and this must be held in view when comparing them with the wet land localities and, especially, when considering the low place occupied by the Cane-breeding Station. After all, the total length of cane is the chief item to be taken into account, and not the enormous rapidity of growth taking place in North India during the months of heavy rainfall and great heat.

But, from the crop point of view, the amount of tillering must also be considered. It is probable that this is greater in the free, light soils of the Gangetic alluvium than in the heavy clays of the Peninsula.[1] But, although it is highly desirable for accurate figures to be obtained on tillering, it has not been possible to include this character in the general measurements taken. And a similar remark may be made as to the relative richness of the juice in different places.

The time at which the sets are sown is of some importance, as little actual growth takes place in North India until the rains come, excepting where there is abundant irrigation. The planting times vary, in our observations, from

[1] Some preliminary figures have since become available on this subject and are included in Memoir No. 4. *Mem. Dep. Agric., Ind., Bot. Ser.*, Vol. X, No. 2.

January in Nagpur to April at the Coimbatore Central Farm. In South India the sets germinate within a week or ten days from planting and, if they do not appear then, it is often the custom to replant the field, but in North India one must sometimes wait for several weeks before there are any signs of the young shoots. To calculate the rate of growth, one should perhaps take the date at which the young shoots appear, because the protrusion of the leafy shoot is the first act of the germinating set, but we have at present no means of determining this date. To obtain a full picture of the relative growth in North India and the tropics, further observations will be necessary, and it may be well to divide it into definite periods as follows :—(1) Period of branching, during which the plant remains low and devotes itself to the business of tillering. This is probably a good deal longer in North India, where the thin canes have far more branches than the thicker South Indian varieties. (2) Period of active elongation of the stem, or cane formation. This is a good deal shorter in North India and probably cane formation is more rapid. (3) Period of ripening. This is better defined in North India, and is with difficulty separated from the growth in length in the South. The careful comparison of these periods in the North and South of India is a piece of work which is well worth doing.

It is, further, to be noted that, in this paper, only indigenous Indian canes are considered, and only a few of these, not perhaps very well adapted for the purpose, as they were the only ones readily available for comparison. There is little doubt that, if the series had been extended and, especially, if thick canes had been included, the differences between the two great regions would have been emphasized. As it was, many of the indigenous canes grown in South India were obviously handicapped by being in uncongenial surroundings, and this is ascribed chiefly to the heavy and impermeable nature of the soil, and the consequent difficulty experienced by the plants in obtaining moisture.

Lastly, the observations were confined to canes growing in Government farms. The conditions on these vary a good deal, much greater care being expended on the plots in some places than in others. It may usually be assumed that the cane growth is better on the farm than in the surrounding cultivators' fields, but this is not always the case. For instance, the wet land in the Coimbatore Farm, although good for paddy, is not specially suited to cane growing. It would not be selected by cultivators for that purpose. Similarly, the land in the Cane-breeding Station, which is eminently suited for compelling the canes to arrow, is not, as yet, sugarcane land. It is probable

that, in these two cases, the growth is inferior to that in the ryots' fields, and there may be other cases where a similar state of affairs exists.

Having due regard to these various pitfalls, it appears from our study that, first in importance, as influencing growth, is the local effect of the *place*, so much so that, within reasonable limits, it is often possible to form an idea as to what kind of canes and leaves are to be expected from growing any cane variety there. The annual variations in the *season* and *treatment* occupy a secondary place, but are sometimes very marked in their effect. Lastly, the *variety grown* sometimes dominates and, in some farms, the individuality of the variety counterbalances the effect of place and climate, as in the strongly growing *Saretha*, the dwarf *Mungo*, and, to a less extent, *Baroukha* and *Chynia*.

III. Characters of cane growth in different places.

From a study of the seven varieties, we have formed the conclusion that any of them at Taliparamba tends to have a large number of long joints; the length of cane formed per mensem is great and the growing season is long; but the canes are of only moderate thickness. The cane ripens quickly. The length of the shoot is great and the width of the leaf is considerable. The curve of joint length commences high, soon reaches its maximum, and that maximum is high. The general growth at Taliparamba is accordingly considered to be satisfactory, the only exception being that the canes are not very thick, and possibly tillering is defective. Taliparamba occupies the first place, in general vigour of growth, of all those at which measurements have been taken with these varieties.

We should naturally regard Samalkota, in the well-known sugarcane tract of the Godavari delta, as equalling Taliparamba in these respects. But, apparently, it is less suited for the growth, at any rate, of North Indian canes. There are only a moderate number of joints formed per mensem and these are of moderate length; the length of cane formed per mensem is thus only moderate and the canes are very thin, but the growing season is long. Ripening takes place quickly. The shoot is of moderate length but the leaf is distinctly narrow. The joint curve starts at a moderate height but is sometimes late in reaching its maximum and that maximum is only moderate.

Nagpur has very long joints, but very few of these are formed per mensem, and they are very thin; the season is long. Ripening is only moderately quick. The shoot is short but the leaf is broad, and so on.

Contrast with these the results obtained at Partabgarh. There are a moderate number of joints formed per mensem, but these are very short, and

the length of cane formed per mensem is small, while the thickness of the cane is not great. The season is short. Ripening proceeds very slowly. The shoot is very short, but the leaves are moderately broad. The joint curve commences low, does not reach its maximum very quickly and that maximum is low. Partabgarh, when compared with the other places noted, shows very poor cane growth. Its suitability for growing these varieties may be doubted, and may have something to do with the predominance of dwarf cane varieties of the *Mungo* type in its neighbourhood.

But, to give the full details of these characters in the various places will take too long, and a table is appended from which similar statements may be prepared for the other localities. The places are classified according to the development of each separate character, and are numbered in class order, the lower number generally indicating better growth, such as greater length or thickness, earlier ripening, and so forth. By averaging the development of all the growth characters in each place, we may, finally, obtain some idea as to general vigour of cane growth in each place.

TABLE II.

Growth characters in different places.

The ten places are marked 1–10 *according to extent of growth.*

	C.B.S.	C. F.	Sam.	Tal.	Nag.	Sab.	Pusa	Part.	Shah.	Alig.
Cane formed per mensem	10	6	5	1	7	3	9	8	3	1
Number of joints per mensem	9	8	6	1	10	3	5	8	4	2
Average length of joint	8	5	7	1	1	5	9	10	4	1
Average thickness of cane	5	3	9	6	8	2	1	7	3	(6)
Number of dead leaves per mensem	5	8	4	1	10	3	9	7	6	2
Length of cane bearing dead leaves	8	7	3	1	6	3	10	9	5	2
Length of shoot	9	3	5	1	8	6	2	10	7	4
Maximum width of leaf	4	4	6	1	2	4	3	3	4	3
Joint curve										
Height of curve at start	8	5	4	1	2	6	10	9	7	3
Distance of maximum from start	4	4	10	1	2	3	6	7	9	8
Height of maximum	9	1	6	1	1	7	8	10	5	4
Average	7·9	5·4	6·5	1·6	5·7	4·5	7·2	8·9	5·7	3·6

IV. The effect of locality on the growth of the different varieties.

A similar table has been prepared to indicate the comparative vigour of growth of each variety in each locality, from which an idea may be obtained as to the relative advantage of growing it there. This takes no account of the class of canes usually grown, nor of the character of the juice or *gur* produced, both of which will be of considerable importance in a final decision.

Table III.

Classification of vigour of growth in each variety in each locality.

	C.B.S.	C. F.	Sam.	Tal.	Nag.	Sab	Pusa	Part.	Shah.	Alig.
Saretha . . .	4	5	6	1	3	..	7	7	..	2
Chin . . .	6	4	7	1	5	..	..	8	3	2
Khari . . .	9	4	2	1	5	5	..	8	7	3
Pansahi . . .	5	3	4	1	..	2	..	5	..	..
Chynia . . .	5	1	4	3	..	2	5	..	..	..
Baroukha . .	5	2	4	1	..	3	..	..	..	..
Mungo . . .	6	..	7	3	4	..	4	..	1	2

In studying this table, the previous one must be held in view, namely, that showing the general vigour of growth of all the varieties tested. A variety comparatively well grown among the local canes of a place, may otherwise appear low down in the list, owing to the poor growth of canes in general in it. The method should afford a ready and accurate means of testing the advantage of introducing a new kind. According to the table :—

Saretha grows well at Taliparamba, Aligarh and Nagpur; moderately well at the Cane-breeding Station and on the Coimbatore Central Farm; poorly at Samalkota; and badly at Pusa and Partabgarh.

Chin grows well at Taliparamba, Aligarh and Shahjahanpur; moderately at Nagpur and the Coimbatore Central Farm; poorly at the Cane-breeding Station; and badly at Samalkota and Partabgarh.

Khari grows well at Taliparamba, Samalkota and Aligarh; moderately at the Coimbatore Central Farm, Nagpur and Sabour; poorly at Shahjahanpur; and badly at Partabgarh and the Cane-breeding Station.

Pansahi grows well at Taliparamba and Sabour; moderately at the Coimbatore Central Farm and Samalkota; poorly at Partabgarh and the Cane-breeding Station.

Chunia grows well at the Coimbatore Central Farm and Sabour; moderately at Taliparamba and Samalkota: and poorly at Pusa and the Cane-breeding Station.

Baroukha grows well at Taliparamba and the Coimbatore Central Farm; moderately at Sabour; and poorly at Samalkota and the Cane-breeding Station.

Mungo grows well at Shahjahanpur and Aligarh: moderately at Taliparamba, Sabour and Pusa; and poorly at the Cane-breeding Station and Coimbatore Central Farm.

From the above summary we see that the individuality of the cane makes its mark throughout the series and, generally, there seems to be a tendency for the growth of varieties to be better near the native habitat of the cane, a result not without its significance.

Similar tables might be prepared, comparing the growth of these varieties and the development of their individual characters in the three regions, *garden land*, *wet land* and *Gangetic alluvium*, and so on; but it is considered that the three tables given will sufficiently demonstrate the method.

V. The effect of the season on the length of the joints.

Two sets of unit observations have been made at Samalkota in the Godavari District of the Madras Presidency, one during 1915-16, on canes ten months old, and the other during 1916-17, on canes 11 months old. On examining the joint curves of *Saretha* obtained in these two years, it is seen that they could not well be more different (Plate III). This fact caused a good deal of trouble, as it appeared generally to discredit the method adopted in this paper. In 1915-16 the first joints were short, they showed an irregular series of maxima and did not attain their greatest length until the 21st from the base, and this maximum was not great; but there were a large number of joints, so that the cane was long. In 1916-17 the first joints were long and quickly attained their maximum (at the 4th joint), this maximum was high, but the number of joints was small, so that, in spite of their length, the whole cane formed was rather short, although the plants had been longer in the ground than in the previous year. This 1916-17 curve was, however, similar to those obtained at other places. The curve of 1915-16 was altogether unique, and unlike that obtained at any other place. The general average joint curve, of all the 89 unit observations, has been added in the Plate for comparison.

Joint Length Curves, Saretha, Samalkota, in 1915-16 & 1916-17, & General Curve, of the Whole 89 Observation Units

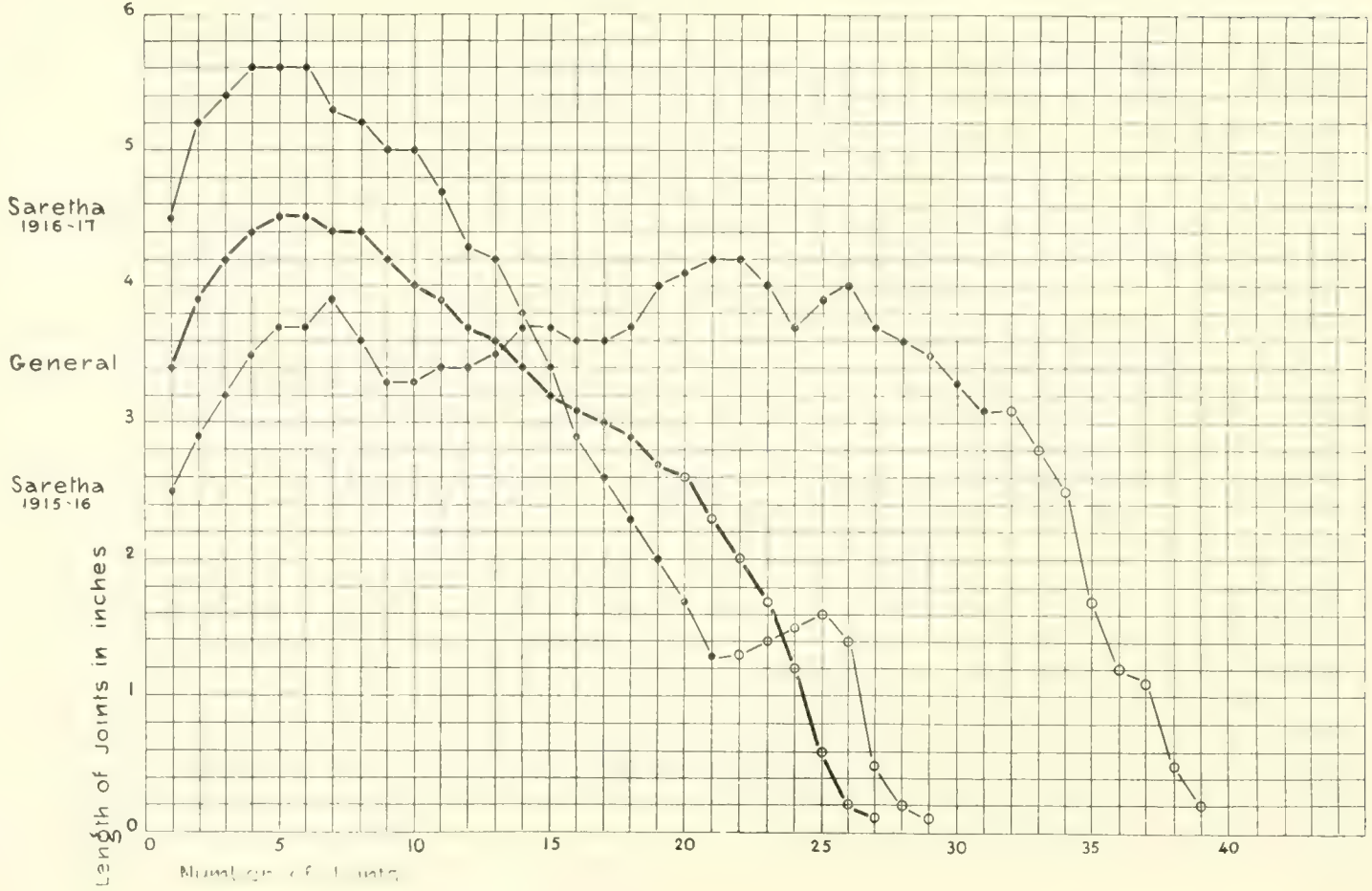


PLATE III.

Joint Length Curves, Samalkota 1915-16

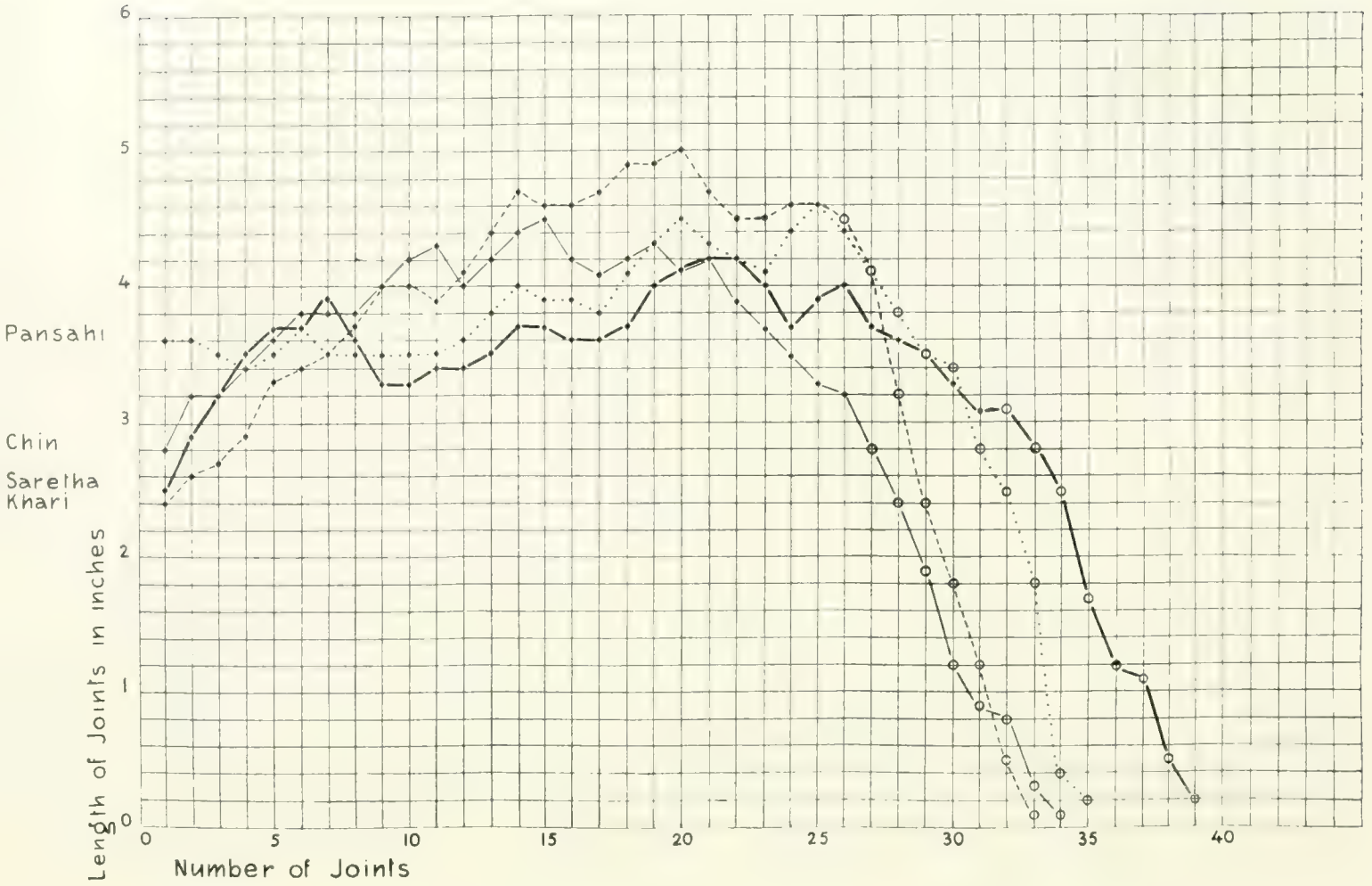
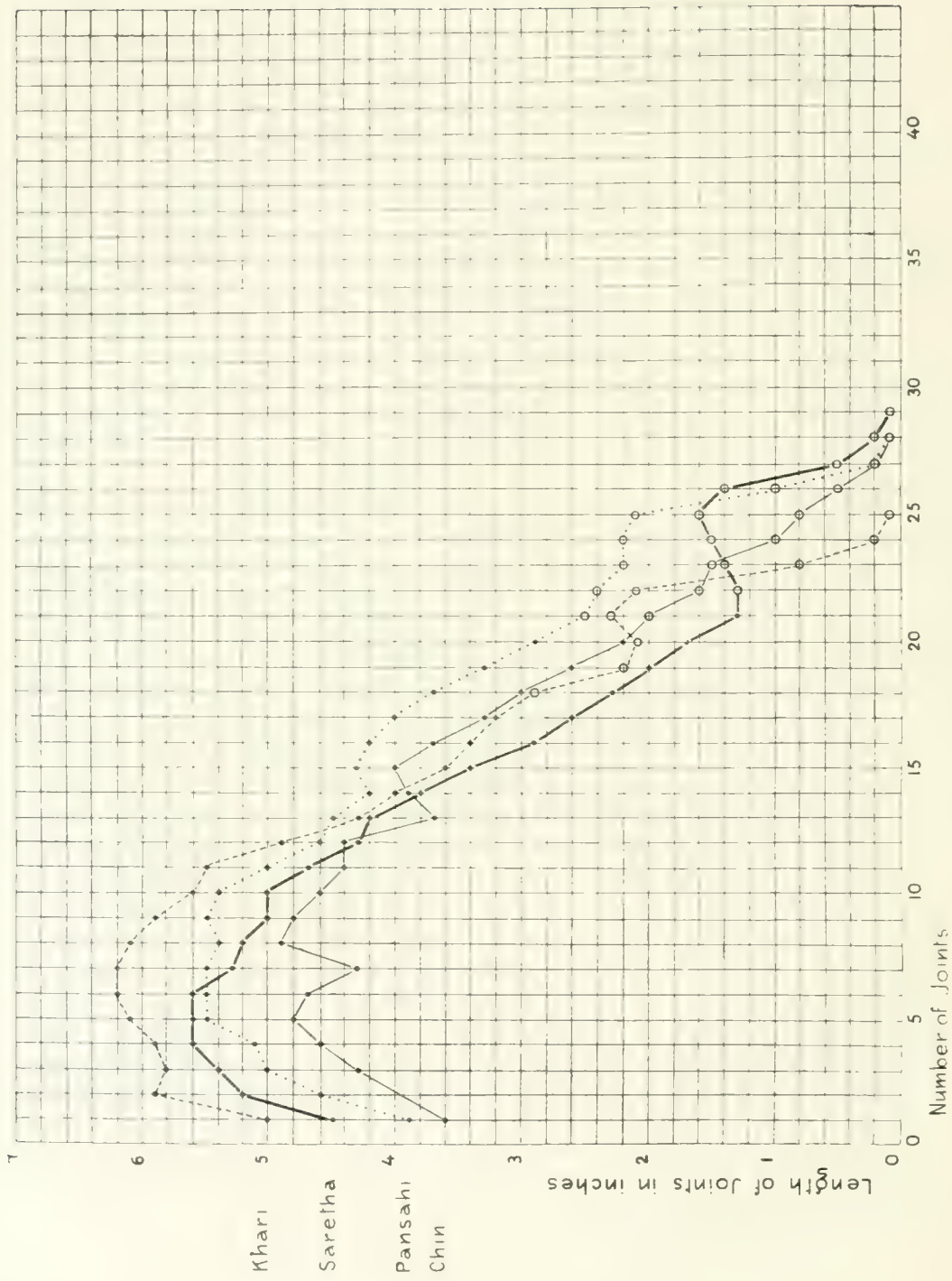


PLATE IV.

Joint Length Curves, Samalkota 1916-17



Now, this difference was so striking that a full study was made of all the other North Indian varieties grown at the same time at Samalkota. It was seen that four of them shared the abnormal joint length curve with *Saretha* (Plate IV). The joint curves of *Saretha*, *Chin*, *Khari* and *Pansahi* were, together, quite unusual in 1915-16, but perfectly normal in 1916-17 (Plate V). A further examination was made of all the other measurements taken in the unit observations, and other differences were noted in these two seasons in various leaf and stem measurements. To clear up the difficulty, a reference was made to the published rainfall and irrigation reports of these two years at the Samalkota Farm.

The conditions in the Godavari delta are peculiar. The water-supply of the delta crops has two different sources: (1) The canals from the Godavari river, depending on rain in Hyderabad and Bombay; and (2) local rainfall, consisting of thunder showers in May and September, and the two monsoons, south-west from June to August and north-east from October to November. In the absence of details for Samalkota, the following analysis of rainfall at Cocanada and Ramachandrapuram, slightly nearer to the coast, may be taken to represent the delta conditions. The figures are for the 45 years before 1914.

TABLE IV.

Rainfall in the Godavari delta. Averages for 45 years.

	Dec.	Jan.	Feb.	Mch.	Apl.	May	June	July	Aug.	Sep	Oct.	Nov.
Cocanada	0·95″	0·18″	0·35″	0·42″	0·52″	1·82″	4·34″	6·00″	5·48″	6·10″	8·75″	4·17″
Ramachandrapuram	0·76″	0·07″	0·23″	0·40″	0·62″	1·88″	5·01″	6·54″	6·36″	7·31″	7·92″	3·69″

The average monthly rainfall may be extracted from the above table, for the periods mentioned above. The dry months, December to April, cold at first but gradually increasing in heat after February, 0·45″; May showers, 1·85″; south-west monsoon, June to August, 5·62″; September thunderstorms, 6·70″; north-east monsoon, October and November, 6·14″.

The canes are planted early in the year, during the middle of the dry, hot weather, and are irrigated by the Godavari canals. But the latter are closed, every year, for cleaning out the silt, for six weeks during May and the first half of June, in preparation for the flood water caused by the south-west monsoon in the area drained by the river. During this stoppage of the canal water, unless there are local showers in the delta (many miles from the collecting area of the river), the canes suffer a set-back, and many of them die. If the

monsoon is later or insufficient, the canals are opened late, and various expedients are resorted to, to keep the canes alive. When the canals are opened, there is abundant water for the rest of the growing period, the only danger being that of water-logging, because of too much rain in September to November. The printed summaries of the weather during the two seasons are quoted from the Samalkota Farm reports.

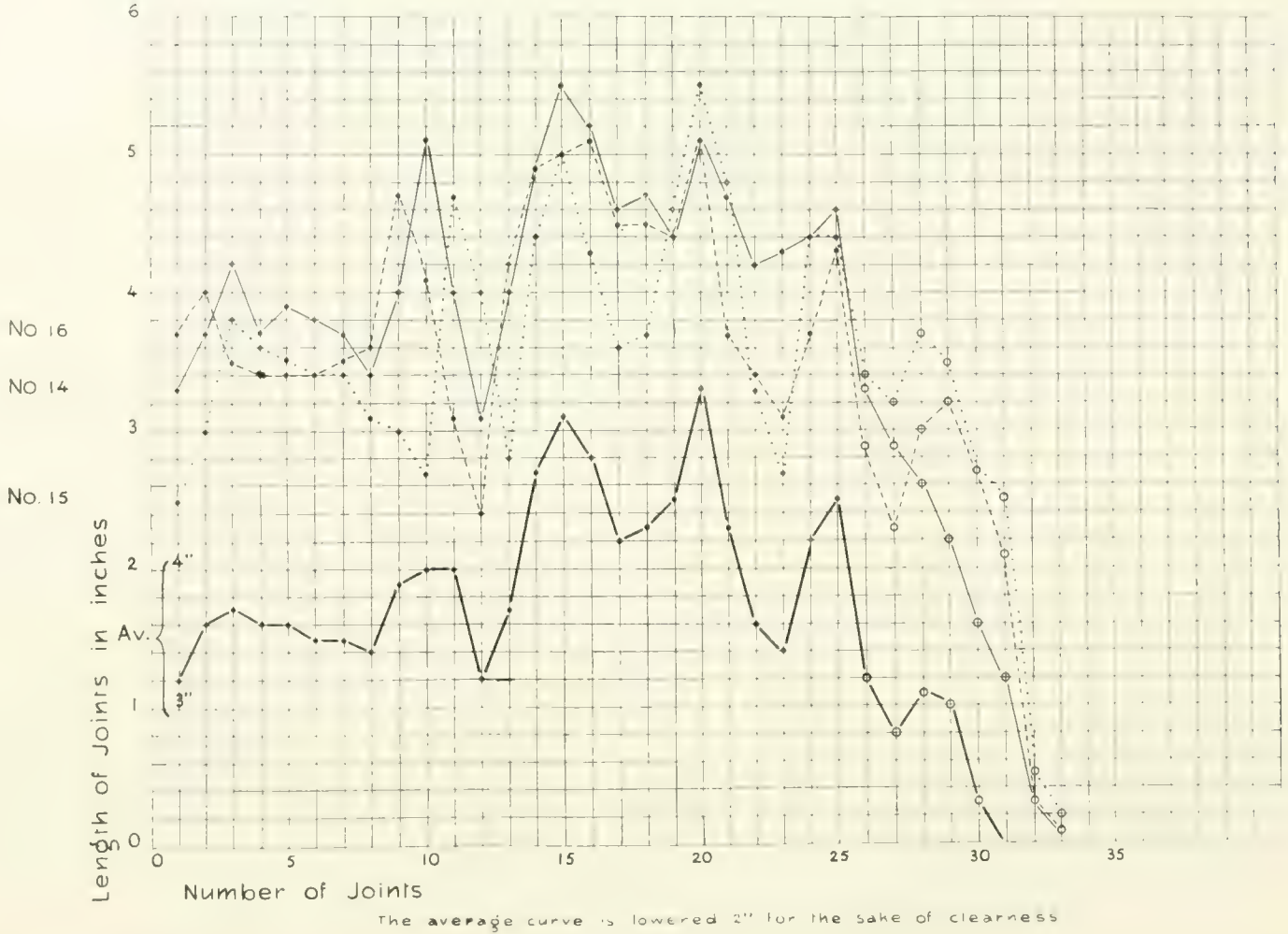
1915-16: "The rainfall recorded for the year was well above the average. The south-west monsoon was late in breaking, the first really heavy shower was not received till the 22nd June and the canals were late in filling..... The season throughout the south-west monsoon was characterized by short spells of rainy weather, followed by considerably longer spells (sometimes of more than a fortnight) of dry weather. The north-east monsoon rains were good and during the whole of November were fairly steady....."

1916-17: "The rainfall recorded during the year was well above the average. The south-west monsoon was very early in breaking, the month of June opened with very heavy showers, and the canals were full unexpectedly early..... The season throughout the monsoon period was characterized by regular and evenly distributed showers and want of rain was never felt. The heavy north-east monsoon rains in October, amounting to 11 inches, seriously interfered with the harvesting of paddy..... The harvest of the longer varieties was also caught in the heavy fall in the latter part of November."

Here we see that although in each year the rainfall was "well above the average," its distribution was very different in the two seasons. The first year was distinctly bad in its first half and good in its second, while the reverse was the case in the second, with its floods towards the end of the year. And these differences in the seasons are permanently engraved on the joint curves obtained. The character of the season was of such a nature that it obliterated the usual characteristic growth of the locality as well as any individual differences in these four canes themselves.

But, while this is so clearly shown in the four cane varieties mentioned above, there is little trace of it in the other two, namely *Baroukha* and *Chynia*. These canes appear to have been little affected by the early drought of 1915-16 and, indeed, their curves are characterized by excessive growth in the early part of the year, as if they were accustomed, or at any rate indifferent, to drought conditions in their early stages. The curves of all six varieties were in close agreement in 1916-17. We have thus a case in which the character of the individual may override that of the season.

Periodicity in Joint Length Curves of three Pansahi Canes with 33 Joints each



The average curve is lowered 2" for the sake of clearness

PLATE VI.

VI. Periodicity in the length of the joints.

An inspection of the general curve of length of joints given above (Plate III), shows that it is fairly uniform in its course. There are few ups and downs. After a comparatively high start it rapidly ascends to a maximum, it then descends gradually for some distance, while, in the last eight joints, the descent is rapid. As a matter of fact, the curve commences at 3·6″, which is the average length of the first joint above ground; the succeeding joints are longer and longer until they reach 4·5″ at the fifth joint; then the joints gradually decrease in length until, at the fifteenth, they are only 2·6″ long; the descent in the last eight is quick until the ultimate joint measured is 0·1″ long. These last eight are more or less immature joints at the top, for all canes are measured from ground-level to that joint at the growing tip which first falls to merely one-tenth of an inch in length; further measurements are not well possible in the field, and the foot-rule used is one divided into tenths of an inch. The curve is smooth throughout its length and there are few irregularities. It is made up of 89 unit observations of 20 canes each and is thus the resultant of over 50,000 separate measurements. It is different with the unit curves, some of which have been reproduced in the diagrams (Plates IV and V), these being the averages of only 20 canes growing at one time and place. The inequalities are greatly increased, and there are a series of ups and downs throughout the length of the curves. But, when we turn to the curves prepared for individuals of these 20 canes, these differences assume larger proportions, and it is not unusual for two consecutive joints to differ by as much as two or three inches in length (Plate VI). The greater the number of canes used in making up a curve, the more uniform is the curve obtained. The general summation curve is in this respect unlike any curve of the whole series, and neither it nor the ordinary varietal curves are to be regarded as *average* joint curves in the usual sense. They are representations of the usual course of events rather than a picture of the average cane of the plot. Such curves have been called elsewhere "ideal," as contrasted with average ones.

There are great difficulties in obtaining such a curve. One of these will readily occur, when it is remembered that the canes of any clump vary greatly in the number of joints, and it is therefore impossible to take an average of them in succession. Again, each cane varies a good deal in the length of its successive joints; some are long and some are short, and in averaging these it will often happen that the long joint in one cane will fall opposite to the short in the next. Any system of averaging will therefore have the tendency to smooth out the differences in different parts, and, the greater the number of canes dealt with, the smoother the resulting curve will be, as is seen in the

cases quoted above. But it is also obvious, if there is anything like periodicity in growth, a rotation of zones of longish and shortish joints following one another, that this periodicity, in any averaging, will also tend to be ruled out and leave little trace behind. We must therefore in this study hark back to the individual curves of separate canes. And, in noting the oscillations in length in successive joints, we must see that the canes compared have as nearly as possible the same number of joints. Three canes of *Pansahi*, grown at Samalkota in 1916, with the same number of joints, have been selected and their joint length curves plotted out on squared paper (Plate VI). The oscillations in these curves, as was to be expected, are very great, but we see at once that there is a regularity in these ups and downs in the three curves, so that we may easily pick out the successive maxima. There being an equal number of joints in the three canes, we can without difficulty average them, and we see that, at fairly regular intervals, there is a zone of increased growth in length, the maxima occurring at the 3rd, 10th, 15th, 20th, 25th and 28th joints. The 28th joint is in the region of those which have not yet completed their growth, while the 3rd is at the base of the plant where disturbances may well occur owing to earthing up and the omission of the joints below the surface. In the middle of the cane there is a regular periodicity in the growth in length of joints. Our example has, frankly, been chosen where this periodicity is rather clearly shown, but it will be seen directly that it is no isolated instance. A method has been devised, by which each set of twenty canes may be judged, as to any periodicity in the length of joints in the individual canes and in the whole series taken together (Plates VII and VIII). The twenty canes are arranged across the page and the number of joints in each cane is indicated by a row of equal squares, the cane with the greatest number of joints being placed at the top, and the others in succession below it, until the cane with the smallest number of joints is reached at the bottom. By this arrangement, any set of canes of equal length are placed together. The first diagram (Plate VII, fig. 1) represents twenty *Pansahi* canes grown at Samalkota in 1915-16, and, in this diagram, the canes numbered 14, 15 and 16 are the ones whose curves are given in Plate VI. The maxima in the length of joints, indicated in the diagram by circles, occur with a certain amount of regularity, the increment being most frequently at every fifth or sixth joint. Thus, in Cane No. 5, they occur at joints 2, 7, 13-14, 19 and 25; in No. 6, at joints 2-3, 8-9, 14-15, 20-21, 26 and 30; in No. 7, at joints 2, 5, 10, 15, 20, 32-33 and so on. Connecting lines have been drawn between the apparently related maxima in adjoining canes, namely, such canes as have the same or nearly the same numbers of joints; and, where such related maxima are

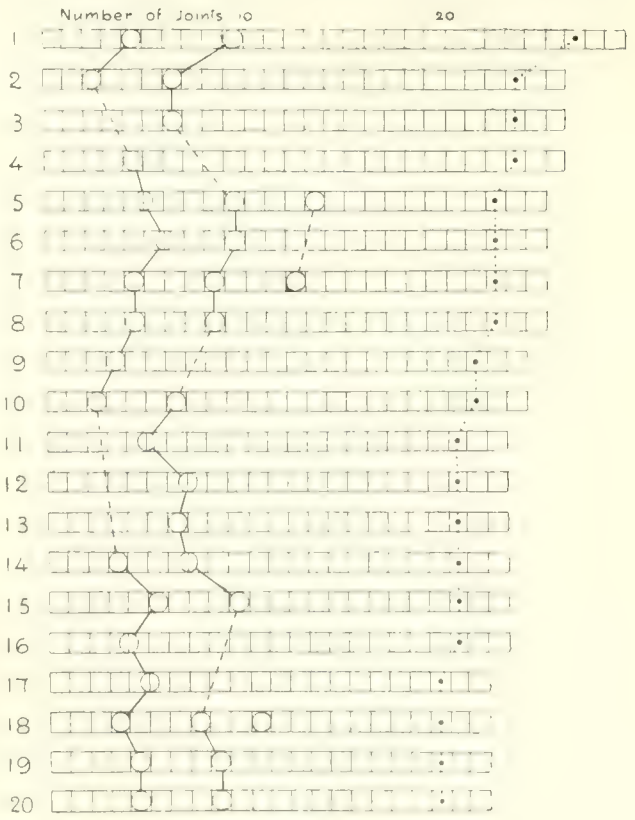


Fig. 2.

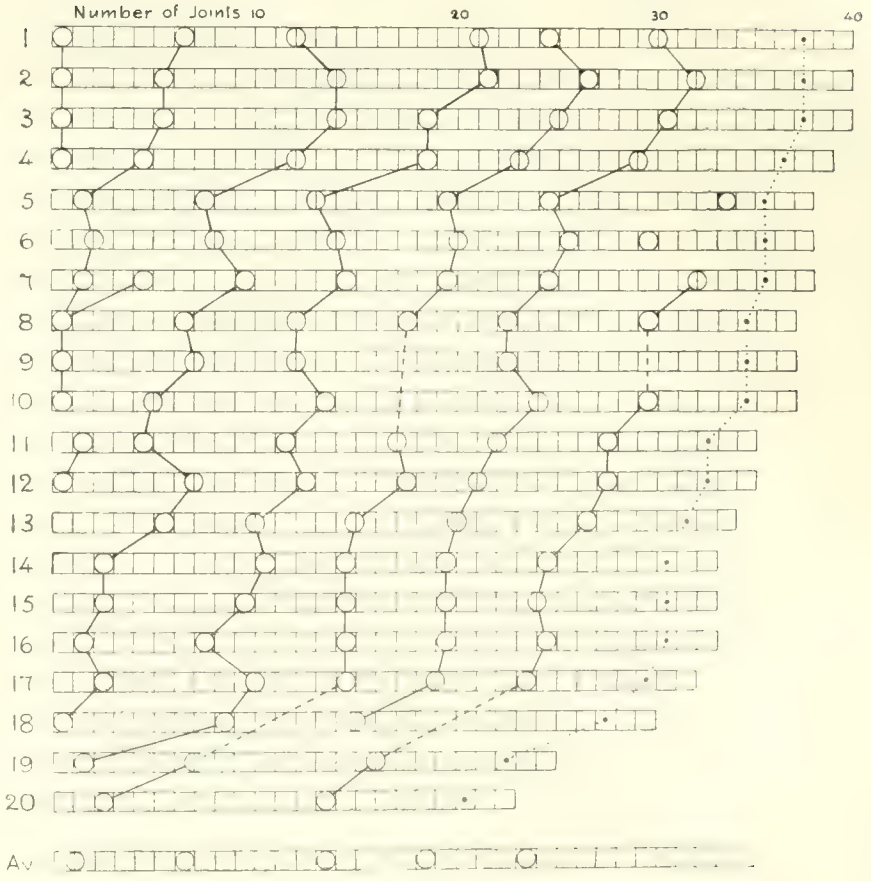


Fig. 1.

Periodicity in maximal joint length. *Pansahi.*

PLATE VII.

Pansahi, Wetland, Coimbatore, 1916-17.

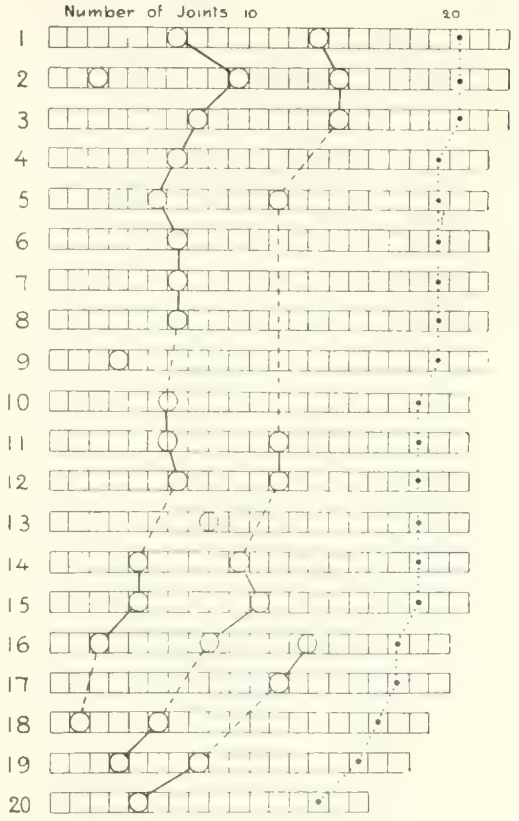


Fig. 1.

Baroukha, Cane-breeding Station, 1915-16.

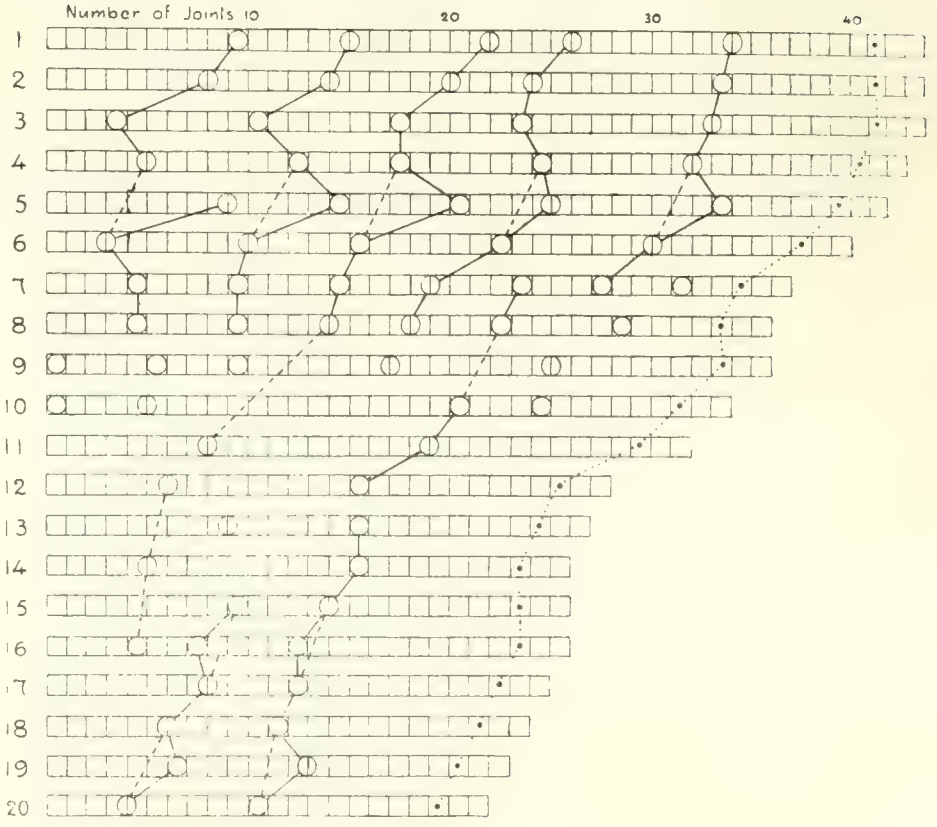


Fig. 2.

Periodicity in maximal joint length, *Pansahi* & *Baroukha*.

absent in adjoining canes, but present in canes slightly removed from one another, as in Nos. 8–10 and 8–11, the connecting lines are broken ones. Lastly, a dotted line is introduced towards the right of the diagram, which gives a general curve of the length of the twenty canes, as judged by the number of joints in each.

Now, it is interesting to note that the lines connecting related maxima in two adjoining canes are often more or less parallel, with one another *and* with the dotted line on the right. Parallelism can be traced, for instance, in the connecting lines between Canes 3 and 4, 4 and 5, 5 and 6, 7 and 8, 8 and 9, 12 and 13, and few adjoining canes are without traces of them. By somewhat arbitrarily joining up all the connecting lines throughout the series, we get a set of maxima curves for the whole twenty canes. In composing them, attention is paid to the undoubted tendency of the connecting lines to run parallel to the dotted line on the right. Although showing numerous irregularities, the general curves of maxima thus obtained are readily seen to be more or less parallel in their course with the curve indicating the length of the canes.

If the periodic stimuli indicated by these curves synchronize, it is natural to suggest their origin in some external cause, acting on all the canes together. If, on the other hand, they do not occur at the same time, we are thrown back on a natural periodicity of growth in the plant, which, in this case, tends to form longer joints once in every five or six. But we have some knowledge of the relative time of origin of these twenty canes. We have learnt elsewhere that the canes of a clump are often easily distinguishable into two classes, early and late in origin, and this shows itself especially clearly in the *Pansahi* group of canes.[1] Among a number of distinguishing characters, the first formed canes have a considerably larger number of joints than those emerging later from the ground. We are justified in assuming from this that the upper canes in the diagram, having the greater number of joints, are early canes, and those towards the bottom of the diagram are late. Arguing from these premises, we may suggest that the first four canes, being the earliest formed, have a very early maximum in length of joint. The next eight, arising somewhat later, have a slightly later first maximum. It is possible that the first maximum in these eight may synchronize with the second maximum of the first four, and this is independently suggested by the maxima curves. Similarly, the next four canes have a still later first maximum, and the connecting lines suggest that these synchronize with the second maxima of the second eight and the third of the first four. Lastly, the last

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 2. Sugarcane seedlings, including some correlations between morphological characters and sucrose in the juice. *Mem. Dep. Agric., Ind., Bot. Ser.*, Vol. VIII, No. 3, July, 1916, p. 159

four, very late canes, have few maxima, and their dotted line suggests that these synchronize with the later maxima of the preceding canes. If this reasoning has any foundation, we have a distinct support to the argument that the general curves of maxima in the twenty canes represent a succession of synchronous growth stimuli, which affect all the canes growing at the time, in other words, that the cause of the stimulus is external. We have been accustomed to look to the *Pansahi* group of canes for clearing up our ideas on many of the processes of growth in the sugarcane plant[1] and this would account for their showing this periodicity in growth better than in the other varieties examined. We have, in the above reasoning, merely attempted to show a possible explanation of the peculiarities in the position of the maxima of joint length. For any certainty to be attained as to the cause of this periodicity, whether external or inherent, the present observational method does not yield sufficient data. A simple series of experiments should be capable of determining the point at issue.

Of the dozen or so examples worked out, three others are added, in which the periodicity in the length of the joints of the cane is observable (Plates VII and VIII). Two of these are from *Pansahi* plots in the wet lands on Coimbatore Farm. In these, the numbers of joints are few and there are also few maxima. The periodicity, as explained above, is however distinctly visible, especially in the case in Plate VII. The variation in the number of joints in the twenty canes is small, and the end dotted line is accordingly more vertical than in the former case, and this uprightness of the curve is reflected in the general maxima curves of each series.

The last example is of *Baroukha* canes grown at the Cane-breeding Station in 1915-16 (Plate VIII, fig. 2). There are a large number of joints, and great variations occur in the twenty canes in this respect. There are also many maxima noticeable in individual canes. Although these are by no means so regularly placed as in the *Pansahi* canes, there is a distinct suggestion of periodicity in many cases. This is fairly obvious in the first eight canes and in the last six, but there are few maxima in the intervening six, and it is not possible to introduce connecting lines in them. There is, moreover, a lack of parallelism, in the diagram, between the connecting lines and the end dotted line. For instance, in Canes Nos. 1–3, with the same number of joints although the connecting lines are more or less parallel, they trend strongly to the left instead of being vertical. In Canes Nos. 3–5, an opposite direction is assumed, the end lines passing down to the left while the connecting lines pass to the

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 4. Tillering of Underground Branching. *Mem. Dep. Agric., Ind., Bot. Ser.*, Vol. X, No. 2.

right. We may perhaps obtain some light on these anomalies by referring to Memoir No. 2, page 162, where it is shown that it is not possible to separate the canes in *Baroukha* into early and late, by the counting of the number of joints formed, as it is in *Pansahi*. It is therefore probable that the arrangement in the table is not that in order of emergence from the ground. Attention is, however, drawn to the broken lines inserted, as in Nos. 4–6, which are not infrequently parallel with one another and with the end dotted line. It is obvious that, if Canes Nos. 4 and 6 had been placed next to one another, the periodicity in the two canes would have been uniform. The same applies to 15 and 17 and to 18 and 20 and, in a slightly less degree, to 1 and 4, the connecting lines in each being approximately parallel with the dotted line. And it is possible that, if we had some reliable method of determining the order in which these canes emerged from the ground, we should be able to compose a diagram showing the periodicity more clearly.